VISUAL AND VERBAL SHORT-TERM MEMORY CORRELATES OF VARIABILITY IN VOCABULARY SIZE

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ABSTRACT

This study investigated the relationship between working memory and language in typically developing young children. The aim was to gain a better understanding of language development, in particular, the involvement of visual and verbal short-term memory in language acquisition and its influence on vocabulary size. It explored possible underlying causes of why some children have problems in the process of learning to talk, whereas other children acquire language easily. A total of 51 New Zealand English speaking children aged two to five completed a battery of assessments measuring receptive and expressive vocabulary and visual and verbal short-term memory. The standardized tests administered included the Receptive One Word Picture Vocabulary Test (Brownell, 2000b), the Expressive One Word Picture Vocabulary Test (Brownell, 2000a), the Visual Patterns Test (Stokes, Klee, Cruickshank, & Pleass, 2009), and the Test of Early Nonword Repetition (Stokes & Klee, 2009a). Receptive vocabulary knowledge was strongly associated with visual (r = .75) and verbal (r = .60) short-term memory performance and age (r = .72). The relationship of expressive vocabulary to visual short-term memory (r = .80) was stronger than to verbal short-term memory (r = .62) but significant for both and also for age (r= .83). Significant unique predictors for expressive vocabulary were age (R^2 change = .60) as well as visual (R^2 change = .04) and verbal (R^2 change = .04) short-term memory. However, age appeared to be the only unique predictor for receptive vocabulary (R^2 change = .54). In addition, the findings suggested that visual and verbal short-term memory increases as children get older. Hence, the Visual Patterns Test and Test of Early Nonword Repetition seem to be good predictors, over and above age, of expressive vocabulary knowledge.

CHAPTER 1

LITERATURE REVIEW

1.1 Introduction

Vocabulary acquisition is a major aspect of language development in children, and the field of language study has focused mainly on researching language itself for the last few decades. However, increasing evidence suggests that working memory, particularly verbal short-term memory, seems to be an important factor in language acquisition (de Abreu, Gathercole, & Martin, 2011; Gathercole, 2006; Gathercole, Service, Hitch, Adams, & Martin, 1999; Jarrold, Thorn, & Stephens, 2009; Stokes & Klee, 2009b). On this account, verbal short-term memory seems to be essential for the correct retention of sound order in words (Baddeley, Gathercole, & Papagno, 1998; Weinrich & Zehner, 2005).

First words typically appear at about 12 or 13 months of age, however, there are variations (Fenson et al., 1994; Paul, 1991). According to Fenson et al. (1994), the average 16-month-old has an expressive vocabulary of approximately 50 words which increases to about 320 words by 24 months of age. Most children experience a “vocabulary spurt”, particularly in receptive vocabulary, between 18 and 24 months (Harris, Yeeles, Chasin, & Oakley, 1995; Mervis & Bertrand, 1995). Research indicates that a child’s vocabulary rises to approximately 600 words by 30 months of age (Bates et al., 1994), and Pinker (as cited in Bee & Boyd, 2007) states that the average vocabulary is about 15,000 words by the age of five or six. Although the majority of children experience vocabulary development typically and within a normal period of time, some children fail to acquire new words normally (Desmarais, Sylvestre, Meyer, Bairati, & Rouleau, 2008). According to Desmarais et al. (2008), such children are frequently referred to as late talkers and they are at higher risk of experiencing specific language impairment (SLI) than typically developing children. SLI is usually associated with delayed vocabulary acquisition and deficits in verbal short-term memory (Baddeley, 2010; Montgomery, 2002). This phenomenon has been investigated in several studies and the results support the theory of memory skills being involved in language development (Alloway, Rajendran, & Archibald, 2009; Coady & Evans, 2008; Hansson, Forsberg, Lofqvist, Maki-Torkko, & Sahlen, 2004).

Nevertheless, some research also suggests that an individual's language knowledge significantly influences short-term memory performance, and that vocabulary expansion itself might be a causal factor responsible for the developmental increase in verbal short-term memory capacity or constraints of it (Gathercole, Hitch, Service, & Martin, 1997; Jarrold, Baddeley, Hewes, Leeke, & Phillips, 2004). This assertion is supported by several studies which found that children's recall of words is higher than nonwords in respect of verbal short-term memory (Gathercole, Frankish, Pickering, & Peaker, 1999; Gathercole, Pickering, Hall, & Peaker, 2001; Hulme, Maughan, & Brown, 1991; Majerus & Van der Linden, 2003; Roodenrys, Hulme, & Brown, 1993). As a result, children with limited linguistic knowledge, thus receptive or expressive vocabulary, are more likely to perform poorer on verbal short-term memory tasks, such as nonword repetition, which would indicate that verbal short-term memory skills are influenced by linguistic knowledge rather than vice versa (Hulme & Roodenrys, 1995).

1.2 Working Memory

There has been considerable interest in the last decade in the cognitive processes involved in language development and a number of studies have investigated memory skills in relation to language acquisition. According to Baddeley (2010), short-term memory (STM) refers to the ability to temporarily store a small quantity of information and it provides the basis for the more recent concept of working memory, which is presumed to be essential in terms of storing information whilst engaging in cognitive challenging activities.

Most research on the topic of memory abilities suggests that memory is composed of several elements (Baddeley, 2010; Logie, 2011; Moscovitch, 1992). Baddeley's model of working memory (Baddeley, 2002, 2003a, 2010), which is one of the most influential models presently available, is comprised of four subsystems: the phonological loop, visuospatial sketchpad, central executive and episodic buffer (see Figure 1). According to Baddeley (2002, 2003b), the phonological loop is responsible for the temporary retention of auditory and verbal input, whereas the visuospatial sketchpad is responsible for temporary retention of visual input. Both systems depend on the central executive, a so-called attention control system for complex cognitive tasks (Baddeley, 2002, 2003b). The central executive is thought to be responsible for the following three attention processes: focusing attention, dividing attention, and switching attention (Baddeley, 2002). In addition, the episodic buffer is assumed to function as a passive, temporary storage system that enables interaction of the various modalities through a multidimensional code (Baddeley, Allen, & Hitch, 2010, 2011). That implies that the episodic buffer may not only link the aforementioned subsystems of working memory but also information from long-term memory and perception (Baddeley, 2010).

Based on the working memory model of Baddeley (2003a), the phonological loop (verbal STM) is a crucial factor in language development, and it is seen as a critical component in the learning of new words. One way to measure verbal STM is to assess nonword repetition, which seems to be involved in vocabulary acquisition and is assumed to be important in the prediction of vocabulary size (Baddeley, 2003a). Moreover, Baddeley's model also suggests that the visuospatial sketchpad (visual STM) might have more influence on language development than previously presumed (Baddeley, 2003a). Baddeley (2003a) argues that it seems to play a part in everyday reading tasks and in speech comprehension since some grammatical structures such as prepositions involve spatial terms, and hence, visuospatial skills are necessary to process the information. Furthermore, it could also be relevant in the process of acquiring new vocabulary in terms of allowing the mental association of tangible objects to lexical and semantic knowledge (Baddeley, 2003a).

1.3 Nonword Repetition

Nonword repetition tasks seem to be reliable and sensitive tools for assessing the verbal component of working memory and have been shown to be a good predictor of children's vocabulary size. In the nonword repetition task, children are presented with nonwords of varying lengths, usually ranging from one to four syllables, and asked to repeat them back as accurately as possible (Stokes & Klee, 2009a). As discussed by Gathercole, Hitch, Service and Martin (1997), by using nonwords, the task ensures that the child has never heard the particular word before, so there is no stored phonological representation of it in the mental lexicon.

A number of studies have examined nonword repetition performance in both typical and atypical language development and have observed correlations between children's nonword repetition skills and language skills (D'Odorico, Assanelli, Franco, & Jacob, 2007; Dollaghan & Campbell, 1998; Montgomery, 2002; Roy & Chiat, 2004; Stokes & Klee, 2009a; Weismer et al., 2000). Gathercole (2006) argues that the ability to produce words not heard before is a fundamental component of language competencies, and that this skill is present in children from the first year of infancy. Nevertheless, research also indicates that the correlation of nonword repetition and lexicon size is normally more present in the early phase of learning a language (Gathercole, 2006; Jarrold, et al., 2004). Children with good nonword repetition abilities have usually better receptive and expressive vocabulary knowledge than children with poor skills at repeating nonsense words (Adams & Gathercole, 2000; Gathercole & Baddeley, 1989; Gathercole, et al., 1997; Gathercole, Willis, Emslie, &

Baddeley, 1992). Thus, nonword repetition can be a significant factor in predicting vocabulary skills before five years of age (Gathercole & Baddeley, 1989; Gathercole, et al., 1992).

1.4 Previous Research

Hick, Botting, and Conti-Ramsden (2005a) examined cognitive abilities in children with SLI to determine whether not only verbal STM deficits but also visuospatial STM deficits were present. The study involved nine children with SLI and a control group of nine typically developing children, with a mean age of 3.9 years. The two groups were matched for mental age on nonverbal abilities (Leiter, 1969). All participants were assessed on three occasions over the period of one year, during which they completed tasks testing verbal STM (digit span), visuospatial STM (pattern recall) and visuospatial processing (block construction). The verbal STM task, assessed with the British Ability Scales (Elliot, Murray, & Pearson, 1978), involved the repetition of auditorily presented sequences of digits, ranging from two to nine digits in length, with five items in each block of numbers. For the visuospatial STM task, based on a measure by Jarrold, Baddeley and Hewes (1999), children were required to recall the position of sharks on coloured paper grids. The difficulty level increased from two to five sharks with five trials at each level. The visuospatial processing task, by Korkman, Kirk and Kemp (2001), involved the copying of a three dimensional block constructed from a three dimensional model, with the difficulty level being increased by copying from two dimensional pictures. Subsequently, a comparison of all the test findings among the two groups was undertaken. The typically developing children scored higher in the verbal STM test than the children with SLI. However, both groups showed similar progress on the verbal STM task and the visuospatial processing task over time. In addition, compared to the typically developing children, the children with SLI made slower progress on the visuospatial STM task. On that account, the study indicated that visuospatial STM deficits might be present in children with language disorders.

Moreover, Hick et al. (2005b) investigated, in a longitudinal comparison over one year, verbal and visuospatial STM and vocabulary development in children with SLI and children with Down syndrome. Nine children with SLI, 12 children with Down syndrome, and 12 typically developing children participated in the study. The groups were matched on mental age, with a mean age of 4.3 years. All children participated in tasks measuring digit span, word span, pattern recall, receptive vocabulary and expressive vocabulary. Digit span and word span were assessed with the British Ability Scales (Elliot, et al., 1978). The digit span task involved the repetition of auditorily presented sequences of digits, ranging from two to nine items in length, with five items in each block of numbers. The word span was tested with the following words: man, hat, toe, cup, and bin. The children were required to repeat three lists of two words in the beginning, with an increase in difficulty of repeating up to five words in a row. For the pattern recall task, the task used in this assessment was like the one used in the previous study by Hick et al. (2005a). The receptive vocabulary was assessed with the British Picture Vocabulary scale II (Dunn, Dunn, Whetton, & Burley, 1997). In this assessment, children were required to point to one picture out of four named by the investigator (sets of 12 items). The Expressive Vocabulary Test by Williams (1997) was used to measure the children's expressive vocabulary and required naming of illustrations. In general, the control group with typically developing children performed higher in all tasks. By the end of the study, vocabulary development was found to be similar in the clinical groups though the children with Down syndrome started with higher scores. The clinical groups achieved similar results in the verbal STM test in the beginning, but only the children with SLI made progress over time. In comparison with the other groups, the children with

SLI made the least progress on the visuospatial STM task. Thus, this study supports the emerging assumption that children with SLI may have deficits in visuospatial STM.

Another study concerning visuospatial immediate memory in SLI was conducted by Archibald and Gathercole (2006). A total of 15 children with SLI, mean age 9.8 years, were compared to two control groups composed of 15 children matched on language age (mean = 6.0 years) and 15 children matched on chronological age (mean = 9.8 years). They were matched on sex, maternal education, and the language control group on British Picture Vocabulary Scale II raw scores. All children participated in working memory and visuospatial STM assessments which were measured with the Automated Working Memory Assessment (Alloway, Gathercole, Kirkwood, & Elliott, 2008). The researchers administered four subtests (Dot matrix, Odd one out, Mr X, Spatial span) of the PC-based Automated Working Memory Assessment. The ‘dot matrix’ task was used to assess visuospatial STM and required the children to point to the position of dots in the same order as they appeared on the screen. The test started with one dot and the difficulty level was increased to nine dots with a maximum of six trials at each length. Visuospatial working memory was tested with the ‘odd one out’ task, ‘Mr X’ figures and the ‘spatial span’ task. In the ‘odd one out’ task, the children were required to first match complex shapes and rule incompatible shapes out, and subsequently they had to recall its position. The level of difficulty was increased to seven boxes at the maximum. For the ‘Mr X’ task, two Mr X figures (one with yellow hat, one with blue hat) with a ball in one hand were presented to the children. The children were asked to remember the location of the ball of the Mr X with the blue hat, and after rotation of the previous mentioned Mr X, both Mr Xs vanished and they were replaced with a circle of eight dots showing the possible positions of the ball. The children were then required to recall the former location of the ball. The level of difficulty was increased to seven Mr X pairs at the maximum. The ‘spatial span’ task required the children to determine whether two identical shapes, one with a red dot, are displayed in the same position or if one is a mirror image. Subsequently, the task continued as the Mr X task (rotation, shapes replaced with dots), and the children were asked to remember the exact position of the dot. Again, a maximum of seven was the highest difficulty level. All three groups showed performance similarities on the tests and the children with SLI actually scored higher on one visuospatial span task. Hence, this investigation didn't support the hypothesis of visuospatial short-term memory difficulties in children with SLI.

A recent investigation by Nickisch and von Kries (2009) assessed STM constraints in children with SLI and potential differences between receptive and expressive SLI, and the study provided substantial evidence of visual STM deficits in children with mixed receptive-expressive language impairment. In this study, 63 German speaking children aged six to eleven, with either expressive language impairment (21) or receptive-expressive language impairment (21), were assessed and compared to a control group (21) on tasks of visual and verbal STM. The control group was matched on nonverbal intelligence and age. Four tests were administered to all children. Verbal STM was assessed with the digit span subtest from the German version of the Illinois Test of Psycholinguistic Abilities (Angermaier, 1977), and nonsense syllables from the Mottier's Test (Linder & Grissemann, 1968). Visual motor STM was measured with the hand movement test of the Kaufman Assessment Battery for Children (Melchers & Preuss, 2003), and visual STM was tested using the visual symbol sequential memory subtest of the German version of the Illinois Test of Psycholinguistic Abilities. In the digit span task, children repeated auditorily presented lists of digits ranging from one to nine. The task started with sequences composed of two digits and continued to a maximum of eight digits. The nonsense syllable span test was comprised of two to six consonant-vowel syllables with a block of six varied syllable combinations for each syllable length (e.g. me-ra, ka-pe-to, mo-na-lu-ra, ge-bi-da-fi-no, bi-ga-do-na-fe-ra). The children were required to repeat the auditorily presented syllables. For both verbal STM tests, the examiner's mouth was hidden to avoid visual input during the tasks. In the hand movement test, children imitated two to six hand movements in the same sequence as performed by the investigator. The visual symbol sequential memory test required the children to recall the exact order of previously displayed unfamiliar symbols. The test started with two symbols and the difficulty level was increased to a maximum of eight symbols with three or four trials for each sequence lengths. In comparison with the controls, both clinical groups scored considerably lower in the verbal STM task. Nevertheless, only the receptive-expressive language impaired children showed difficulties in visual STM.

A synopsis of the previous research examining both children's visual and verbal STM skills regarding language is presented in Table 1.

1.5 TENR and VIP

Stokes and Klee (2009a) developed the Test of Early Nonword Repetition (TENR) to assess verbal STM in children from two years of age and over. The test was designed to examine nonwords of one to five syllables in length, while being low on word-likeness and articulatory complexity at the same time (Stokes, et al., 2009). According to Stokes and Klee (2009a), children are asked to imitate the nonwords from live adult speech, and subsequently roll a ball down a sliding board as a reward. Each correct phoneme is awarded a point with no deductions for insertions, and children's habitual articulation errors are scored as correct (Stokes, et al., 2009). In a study, investigating the diagnostic accuracy of the TENR for two-year-old children (full sample, N = 232), it was found that late talkers scored significantly lower than typically developing children (Stokes & Klee, 2009a). Another study, consisting of 45 children aged two to four, examined the association between children's receptive and expressive vocabulary scores and their performance on the TENR (Stokes, et al., 2009). It was not only found that the participants' scores on the TENR were highly correlated with receptive and expressive vocabulary knowledge in the age range tested, but also that children's scores on the TENR increased with age (Stokes, et al., 2009).

In addition, Stokes and Klee developed the Visual Patterns Test (VIP), based on the Shark Test (Hick, et al., 2005a, 2005b) and the Visual Grid Test (Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999), to assess visual STM in children as young as two years of age (Stokes, et al., 2009). The test was designed to examine the recall of visual patterns with as less spatial, kinaesthetic and sequential information as possible, while being low on verbal encoding at the same time (Stokes, et al., 2009). The stimulus are two to five fish, presented for five seconds in grids (20 in total) on pages, some with fish in the boxes and some without, and every correct grid is awarded one point with a maximum score of 20 points (Stokes, et al., 2009). In a VIP pilot study, visual STM in relation to vocabulary and verbal STM was investigated in 30 typically developing children aged 25 to 37 months (mean age = 29.8 months), however, it was found that the VIP was not associated with any of the former mentioned variables, when the effects of age were controlled (Stokes, et al., 2009).

1.6 Summary

As can be seen, the majority of research in the area of working memory and its relation to language development in children has focussed predominantly on the verbal STM aspect. Although some studies have investigated visual STM, results vary and indicate inconsistencies. One possible explanation might be the small sample size of some of these studies. A total of only 18 to 63 children, except for Stokes and Klee (2009a), were assessed in the individual studies which might limit the analysis and interpretation of results. Moreover, some of these studies (Archibald & Gathercole, 2006; Hick, et al., 2005b; Nickisch & von Kries, 2009) only assessed visual and verbal STM in older children who had already completed most of the milestones in the language development process. However, these older participants might also have developed compensatory strategies, which they could have applied during the assessments. For example, some children may have used lip-reading as a visual compensation for verbal STM deficits in the nonword repetition task, and only Nickisch and von Kries (2009) mentioned an exclusion of these negative influencing factors. In addition, Nickisch and von Kries (2009) were the only researchers who made a distinction between expressive language impairment and mixed receptive-expressive language impairment, and considered this in their study. Therefore, group results in the other studies might distort individual results.

However, with the exception of Archibald and Gathercole (2006), all of the above studies suggest that children with SLI may not only have deficits in verbal STM but also in visuospatial STM (Hick, et al., 2005a, 2005b; Nickisch & von Kries, 2009). These researchers also agree that further research in the area of verbal and visuospatial STM, and its correlation to language development, is required.

CURRENT STUDY

The purpose of the this study was to research the relationship between two components of the working memory system, thus visual and verbal STM, and vocabulary size in two to five year old monolingual children. Whereas previous studies have investigated verbal STM in children and found correlations to language development, only a few studies have looked at visual STM in relation to language acquisition. Moreover, these results in terms of visual STM seem to show inconsistencies in whether it is a predictor of language skills or not. Nonetheless, a few previous investigations indicated that not only verbal but also visuospatial STM may have an impact on language development. Consequently, the current study had three major objectives: (1) Providing novel information on visual and verbal STM skills in terms of vocabulary acquisition; (2) Exploring associations among verbal STM and vocabulary size further; (3) Determining the predictive value of these factors on receptive and expressive vocabulary development. Based on the previous research in this area it is hypothesised that:

(a) Performance on the TENR correlates positively with expressive vocabulary assessment results. Thus, children with lower scores on the TENR will also perform at a lower level on the Expressive One Word Picture Vocabulary Test (EOWPVT).

(b) Performance on the VIP correlates positively with receptive and expressive vocabulary assessment results. Thus, children with lower scores on the VIP will also perform at a lower level on the Receptive One Word Picture Vocabulary Tests (ROWPVT) and EOWPVT.

(c) Performance on the VIP correlates positively with performance on the TENR. Thus, children with difficulties on the VIP also show difficulties on the TENR.

(d) Visual and verbal STM increases as children get older.

CHAPTER 2

METHODOLOGY

This study was approved by the Human Ethics Committee of the University of Canterbury on 13 June 2011. The approval number is HEC 2011/38.

2.1 Participants

A total of 51 children, aged two to five, participated in the study. The group of participants consisted of 24 males and 27 females with a mean age of 3.5 years. Of these 51 children, 18 were recruited from the Team Tamariki research database (http://www.nzilbb.canterbury.ac.nz/team%20tamariki.shtml) and other sources, the other 33 children were recruited by the author of this paper by contacting kindergartens and schools (see Appendix C). All children were monolingual, native New Zealand (NZ) English speakers, and none had hearing impairments, or suffered from significant medical, neurological or psychological problems according to parent reports. Detailed information about their socioeconomic status was not collected, but informal discussions with parents confirmed that the majority of children were from middle and upper-middle class families with a high educational background. Parental consent was obtained for each child participating in the study. Participants were excluded from the study if they were not monolingual English speakers; otherwise there was no inclusion requirement with respect to language development.

Beforehand, the parents received an information sheet (see Appendix D) with details of the study and they were invited to discuss the project with the principal researcher. If they decided to join the study, they were required to sign a consent form and to fill in a questionnaire concerning the child's birth order, siblings, ethnicity, medical condition and language(s) spoken at home (see Appendix E and F).

2.2 Design and Procedure

All participants were seen individually in a quiet area with minimal distraction either at the Child Language Centre (University of Canterbury), their home or school/kindergarten, depending on parental preferences. In total, 39 children were seen at the Child Language Centre, 11 children were seen at their homes, and one child was seen at his kindergarten. A parent or caregiver was present at all times during the appointment. The tests were all administered by the principal researcher, a qualified Speech and Language Pathologist, and the participants were able to request breaks at any time during the session. Each assessment lasted about an hour per child and all four tests were administered within one session. The four tests described below were administered to all children: ROWPVT (Brownell, 2000b), EOWPVT (Brownell, 2000a), VIP (Stokes, et al., 2009), TENR (Stokes & Klee, 2009a).

ROWPVT: Receptive vocabulary. Before the test was administered, the child's chronological age was determined to identify the first test item and the task was explained to the child: *"I am going to show you some pictures, and I want you to point to or tell me the number of the picture that is the same as the word I say."*

The task explanation was altered for the two year old children to a less complex form: *"I am going to show you some pictures, and I want you to point to what I say."*

Four example items were presented to the child to ensure comprehension of the task. Subsequently, the child was shown pictures with four illustrations, starting at a point considered to be age or language level adequate, and was required to point to the illustration named by the examiner. A basal of eight consecutive correct responses was established and the assessment continued until a ceiling of six incorrect responses out of eight consecutive items was obtained. The items were ordered with regard to their difficulty level. Due to the fact that there are no NZ English receptive vocabulary tests available at this time, an American English vocabulary test was used. The American word *faucet* was replaced with *tap* which is more common in NZ English. The administration of the ROWPVT took about 20 minutes.

EOWPVT: Expressive vocabulary. Before the test was administered, the child's chronological age was determined to identify the first test item and the task was explained to the child: *"I am going to show you some pictures, and I want you to tell me the word that names each picture or group of pictures."*

The task explanation was altered for the two year old children to a less complex form: *"I am going to show you some pictures, and I want you to tell me what you see."*

Four example items were presented to the child to ensure comprehension of the task. Subsequently, the child looked at pictures with an object, action or concept, starting at a point considered to be age or language level adequate, and was asked to name them. A basal of eight consecutive correct responses was established and the assessment continued until a ceiling of six consecutive incorrect responses was obtained. The items were ordered with regard to their difficulty level. Due to the fact that there are no NZ English expressive vocabulary tests available at this time, an American English vocabulary test was used. The following American pictures were replaced with images of objects/actions/concepts that are more common in NZ:

- *Corn* was replaced with *carrot*
- *Wagon* was replaced with *pram/pushchair/buggy/stroller*
- *Racoon* was replaced with *possum*
- *America/U.S.(A.)/United States (of America)* was replaced with *New Zealand*

The administration of the EOWPVT took about 20 minutes.

VIP: Visual short-term memory. A new computerized version of the VIP was used for the assessments. Pictures of fishbowls, some with fish and some without, were presented on a computer touch-screen. The fish disappeared after a five second stimulus exposure time, and the child had to remember the exact location responding by touching the fishbowl on the screen where the fish was. The instruction phase had three attempts only and the purpose of this phase was to train the child to touch the screen in response to the stimuli. If the child failed to understand what was required of him/her then the program was restarted to repeat the instructions. The test was introduced with one fish on the screen and the test instructions were as follows: *"You are going to see a fish swimming in his bowl. He is going to swim away and you can bring him back by touching his bowl. Watch carefully. Are you ready?"*

The first fish appearance during the training trail was commented by the researcher saying the following to the child: *"There is the fish. He is swimming, swimming, swimming away. You bring him back. Touch his bowl."*

If the child was not able to locate the one fish during the training trial, he/she was assisted by the investigator. After the three instruction trials, test phase one appeared which was annotated with the following: *"Now there are two fish. Watch carefully. Look, here are two fish swimming in their bowls. They are going to swim away. Can you bring them back?"*

The actual testing involved 12 trials during which the difficulty level increased to two fish, three fish, four fish and five fish. If needed, a short break between each test phase could be taken. The administration of the VIP took about 10 minutes.

TENR: Verbal short-term memory. A new computerized version of the TENR was used for the assessments. The child repeated auditorily presented nonwords (see Appendix G), and subsequently saw a cartoon character on the computer as a reward. The instruction phase included as many attempts as the child needed, on average one to three, and the purpose of this phase was to train the child to imitate the nonwords presented on the computer. The test was introduced with the word "teddy" and the test instructions were as follows: *"We are going to see some funny people. They will come when you say their name. Let's practice."*

The test started with four one-syllable nonwords, and then the difficulty level increased to four two-syllable, four three-syllable, four four-syllable and four five-syllable nonwords, in total 20 words. Each nonword was presented only once and none were repeated. The TENR was audiotaped and played on a computer to ensure the consistency of delivery to each participant. An Olympus Digital Voice Recorder WS-450S with an external microphone was used to record all TENR assessments. The administration of the TENR took about 10 minutes.

2.3 Data Analysis

Statistical analyses were undertaken using SPSS version 20.

ROWPVT and EOWPVT. The child's responses were scored as correct or incorrect, and each correct word was awarded with one point. All responses below the basal were considered to be correct. The total number of correct responses was calculated and a raw score was obtained. Subsequently, the standard score and the percentile rank were derived from the raw score.

VIP. Two dependent measures were calculated, one based on the number of correct trials (12) and another based on the correct number of fish recalled (42). There were three trials each for screens presenting two, three, four and five fish, and the child was awarded with one point for each correct trial/fish, in total 12/42 points. At the end of the test, the final score was automatically calculated by the computer.

TENR. The nonwords were all transcribed, using a broad IPA transcription, by the principal researcher either during the session or after the session (audio recordings). Additionally, a second transcriber was recruited to independently transcribe all the data for each child using the audio recordings, i.e. the second transcriptions were done without any knowledge of the first transcriptions. This was done since the principal researcher's native language is German and not English. Transcriptions included all vocalisations and nonword repetition attempts made by the child. Responses were scored as incorrect if the investigator considered the sound produced by the child to differ from the target sound. For cases in which it was obvious from a child's spontaneous speech and expressive vocabulary tests that a specific sound was consistently substituted with another sound (e.g. [t] for /k/), substituted phonemes were counted as correct. The child scored one point for each consonant and each vowel in the correct sequence; subsequently, the total number and percentage of phonemes repeated correctly was calculated. Any phoneme omissions were scored as incorrect; however, no deductions occurred for phoneme additions. All tests were scored by the principal researcher but the phonetic transcriptions of the second transcriber were used for the statistical analysis, since they were a native speaker of NZ English.

2.4 Scoring Agreement

ROWPVT and EOWPVT. In total, 11 out of the 51 participants were randomly selected and re-scored on the ROWPVT and EOWPVT by the author's principal supervisor to check inter-judge agreement. The inter-judge agreement for both vocabulary assessments was 100%.

VIP. No scoring checks were conducted for the VIP since a touch screen captured each response, and the final score was automatically calculated by the computer.

TENR. Although the transcriptions of the second transcriber were used for the final statistical analysis, the principal researcher used just over 20% of the samples to calculate transcription agreement and disagreement of phonemes. There was an average of 82% agreement (range = 65-92%) in broad phonetic transcription between the two independent transcriber across the 11 pairs of transcripts. The differences in scoring were mainly due to vowel disagreements rather than consonant disagreements. Word length also seemed to influence word perception and resulted in minor differences in scoring.

CHAPTER 3

RESULTS

A total of 51 children participated in the study and the ROWPVT and VIP were administered to all of them. Of this sample, 49 participants completed the EOWPVT, and the remaining two were excluded from the assessment since no expressive language was present at the time of the testing. This resulted in missing data for 4% for the EOWPVT. Complete data for the TENR was obtained from 38 children (TENR compliant group), and incomplete test results were provided for a further 13 children (TENR non-compliant group). The data from these 13 children are not included in the statistical analysis of the TENR resulting in 25% of missing data. Consequently, complete data on all four measures were available for a total of 38 children.

3.1 Descriptive Statistics

Descriptive statistics with means, standard errors, standard deviations and ranges for all measures, and number of children completing each measure (full sample, N = 51) , are provided in Table 2.

Children in the TENR compliant group were older on average with a mean age of 45.34 months, and they scored higher on all the other measures than children in the TENR non-compliant group with a mean age of 32.85 months (see Table 3). The mean percentage of phonemes correct for each number of syllables in the TENR is illustrated in Figure 2.

The scores of the boys and girls did not significantly differ on any measure ($p > .05$ for ROWPVT, EOWPVT, VIP and TENR), and so were combined in all subsequent analyses.

3.2 Correlation Analysis

Pearson correlation coefficients were computed to ascertain the relationship among the tasks.

The association between trial and fish scores on the VIP was very high ($r = .92$, $p = .001$). Therefore, all the correlations for the VIP were solely focused on the fish scores. The same applies for the phoneme (i.e. percent phonemes correct) and consonant (i.e. percent consonants correct) scores on the TENR ($r = .98$, $p = .001$). This calculation, controlling for phoneme-consonant correlation, was based on the full TENR sample; however, the relationship remains strong even when subdividing the sample into sections for the one to five syllable nonwords. On that account, only the phoneme scores are utilised in the correlation and regression analyses. This is consistent with previous research examining nonword repetition, which also focused on the percent of phonemes correct in the interpretation of test results (Roy & Chiat, 2004; Stokes & Klee, 2009a).

Bivariate correlations for vocabulary and memory measures are presented in Table 4. All four measures, ROWPVT, EOWPVT, VIP and TENR, correlated significantly with age ($r = .72$, $.83$, $.79$ and $.58$ respectively, $p = < .001$ in all cases), and the relationships are displayed in Figures 3, 4, 5 and 6. Within each area of cognitive skill, measures significantly correlated with each other (see Figures 7, 8, 9, 10 and 11). The receptive (ROWPVT) and expressive (EOWPVT) vocabulary scores were highly interrelated ($r = .82$, $p = < .001$), as were the visual (VIP) and verbal (TENR) STM scores ($r = .55$, $p = < .001$). Visual STM performance was strongly associated with receptive ($r = .75$, $p = < .001$) and expressive ($r = .80$, $p = < .001$) vocabulary knowledge. The relationship of verbal STM to expressive vocabulary ($r = .62$, $p = < .001$) was slightly stronger than to receptive vocabulary ($r = .60$, $p = < .001$) but significant for both. Correlations among vocabulary and verbal STM increased with higher levels of difficulty in the TENR and appeared to be strongest for the five syllable nonwords.

Table 5 shows the partial correlations, after having removed the effect of age, and indicates those significant at the .001 and .05 level. The relationship between the ROWPVT and the EOWPVT remained highly significant ($r = .61$, $p = < .001$) but the VIP and TENR were no longer interrelated ($r = .21$, $p = > .05$). No significant correlation was revealed between visual STM and receptive vocabulary ($r = .27$, $p = > .05$), however, a moderate correlation was still evident for expressive vocabulary ($r = .40$, $p = < .05$). Even when age was partialled out, consistent associations of moderate significance were found between verbal STM and both receptive and expressive vocabulary ($r = .31$ and .33 respectively, $p = < .05$ in both cases).

3.3 Regression Analysis

Hierarchical multiple regression analyses were conducted. The predictor variables of age, TENR-PPC, and VIP total fish score were regressed onto the dependent variable, ROWPVT in one analysis and EOWPVT in another analysis, in order to determine how much variance in children's vocabulary scores could be accounted for by the three predictors. These analyses were conducted using the 'Enter' command in SPSS to force age into the equation first, followed by the other two predictor variables together.

Table 6 shows that children's receptive vocabulary can be predicted by age, with 54% of the variance in receptive vocabulary accounted for. Adding the two STM measures to age increases the amount of variance accounted for by 6%, but this was not statistically significant.

A three-step hierarchical multiple regression analysis was conducted, with age entered on the first step, TENR score entered on the second step, and VIP score entered on the final step. Table 7 summarises the results of this analysis using these three variables to predict children’s expressive vocabulary raw scores on the EOWPVT. As expected, age alone accounted for 60% of the variance in children's expressive vocabulary scores ($p < .001$), with TENR-PPC scores accounting for an additional 4.4% over and above age (R^2 change, $p < .05$), and VIP scores accounting for an additional 4.4% of the variance over and above the other two variables (R^2 change, $p < .05$). This shows that children's expressive vocabulary can be predicted by a combination of age and the two STM measures, with a total of 69% of the variance in expressive vocabulary scores accounted for. It also shows that of the two STM measures, the VIP score appeared to be the more important, judging from the size of the standardised beta values (.33 for TENR vs. .20 for the VIP).

CHAPTER 4

DISCUSSION

The purpose of the study was to examine the effect of different factors influencing vocabulary development in typically developing young children aged two to five. Specifically, it aimed to establish whether a significant association between receptive and expressive language knowledge and working memory performance was evident.

Following considerable evidence for verbal STM involvement in vocabulary development (Baddeley, 2003a; Baddeley, et al., 1998), it was hypothesized that (a) performance on the TENR would correlate positively with the EOWPVT; and, given that there is increasing support for theories considering visual STM contribution to language acquisition (Baddeley, 2003a), it was also hypothesized that (b) performance on the VIP would correlate positively with the ROWPVT and EOWPVT. In addition, with respect to the close relationship of visual and verbal STM, it was further hypothesized that (c) performance on the VIP would correlate positively with performance on the TENR and that (d) visual and verbal STM would increase as children get older.

An important finding of this study was the equally significant contribution of visual and verbal STM to expressive language. Although a positive correlation between receptive vocabulary and working memory was indicated, it was not found to be statistically significant. The results suggested that visual and verbal STM are associated, but only when not controlling for age. As hypothesised, visual and verbal STM increases as children get older, and the same accounts for receptive and expressive language abilities.

4.1 Findings

The findings of the current study support the concept that language development may not be accounted for by only a single process. Several cognitive components, thus working memory, are assumed to be involved in the process. A number of studies have investigated working memory components and most research agrees on verbal STM involvement in the process of language acquisition (de Abreu, et al., 2011; Gathercole & Baddeley, 1989; Gathercole, Service, et al., 1999; Stokes & Klee, 2009b). In contrast, less consideration was given to the visual component of working memory and its contribution to language development. Although other studies have suggested that visual STM may be involved in the process of language acquisition, the exact relationship between language and visual STM remained indistinct (Adams & Gathercole, 2000; Hick, et al., 2005a, 2005b). However, the current study suggests that the influence of working memory on language not only involves the verbal domain but also the visual domain. These findings contrast with previous research by Archibald and Gathercole (2006), investigating the visual component of working memory in terms of language development, where no such evidence was found.

Referring to the results of the present study, it should be noted that boys and girls did not differ significantly on any measure. This is in contrast with Stokes and Klee (2009b) who found that the gender of the child makes a difference in vocabulary and verbal STM scores. The phenomenon in this study might be explained with the high educational and socioeconomic background of the participant's parents. This assumption was confirmed through informal discussions with the parents. However, a study conducted by Roy and Chiat (2004) indicated that nonword repetition is independent of both gender and socioeconomic class. Therefore, another explanation might be that the age range in the current study was much greater than in the study by Stokes and Klee (2009b), thus, as children get older the gender difference may disappear.

Interestingly, when assessing the receptive and expressive vocabulary knowledge, it was observed that the majority of children presented with high standard scores for both the ROWPVT (mean = 112.53) and EOWPVT (mean = 112.58). A consideration to keep in mind is that these standard scores are all based on American children. Hence, the results should be interpreted with caution. One possible explanation for the high standard scores might be that children in NZ have better vocabulary knowledge than American children. However, again, a more plausible explanation would be the high educational and socioeconomic background of the participants. Therefore, it is likely that the children had generally higher language abilities than most children in the population, due to the parents who volunteered their children to participate in this study. A confirmation of this is not available, since no measure of parent education level or socioeconomic status was collected in the present study. Nevertheless, in contrast to this assumption are findings by Stokes and Klee (2009b), which stated that children's socio-emotional status and mothers' educational level were not statistically related to children's vocabulary scores.

In respect of the nonword repetition task, 75% of the entire sample completed the TENR. The rest of the sample either did not start or did not complete the test for reasons ranging from absence of expressive language (two), to fatigue and lack of concentration (three), and refusal to attempt the task or parts of it (eight). Consequently, these participants were excluded from the subsequent statistical analysis of the nonword repetition task resulting in 25% of missing data. Nevertheless, it should be noted that the non-compliant children were younger on average with a mean age of 32.85 months. This is consistent with other studies investigating nonword repetition in young children who also experienced a loss of children due to non-cooperation (Roy & Chiat, 2004; Stokes & Klee, 2009a).

In the bivariate correlation analysis, all four measures, including ROWPVT, EOWPVT, VIP and TENR, demonstrated highly significant correlations among each other and with age. Thus, as age increases both receptive and expressive vocabulary knowledge increase. The same applies to visual and verbal STM abilities. The finding in terms of verbal STM is in line with Roy and Chiat (2004) and Stokes et al. (2009) who also found that nonword repetition, thus verbal STM, increases as children get older. Furthermore, a large variability along the age continuum from two to five was observed for both receptive and expressive vocabulary. The same accounts for verbal STM. For the visual STM, more variability was observed in younger children below the age of four than in older children.

Subsequently, further calculations in the form of partial correlation analyses were conducted and resulted in less significant associations of the variables. Consequently, visual STM no longer correlated with verbal STM and receptive vocabulary. Nevertheless, a moderate correlation was still present between visual STM and expressive language. The vocabulary tests continued to display a strong relationship. In addition, verbal STM was still associated with both receptive and expressive language, even when age was partialled out. This is consistent with Stokes et al. (2009), who also found that children’s performance on the TENR is highly correlated with receptive and expressive vocabulary scores. However, other studies, investigating nonword repetition, only found a link to either receptive vocabulary (Gathercole & Adams, 1994; Roy & Chiat, 2004) or expressive vocabulary (Edwards & Lahey, 1998). Hence, it becomes apparent that nonword repetition requires further investigation for both receptive and expressive vocabulary to determine its specific relationship to language abilities.

Finally, a hierarchical regression analysis was conducted to establish the amount of variance in vocabulary that can be accounted for by visual and verbal STM and age. As expected, for both vocabulary tests, age was found to be the most significant predictor of vocabulary development. Children’s receptive vocabulary was predicted by age, with 54% of the variance accounted for. Adding the two STM measures to age increased the amount of variance accounted for by 6%, but was not statistically significant. Thus, no meaningful relationship was found between receptive language and working memory over and above what was predicted by age. However, significant and highly consistent links were observed between visual and verbal STM performance and expressive vocabulary knowledge, with the children scoring more highly on the memory tasks also scoring at a superior level in the expressive language assessment. It was revealed that children's expressive vocabulary can be predicted by a combination of age and the two STM measures, with 69% of the variance in expressive vocabulary being accounted for. It also showed that of the two STM measures, the VIP score appeared to be the more important of the two. On this account, the findings suggest that children with difficulties in visual and verbal STM memory are more likely to score lower in the expressive vocabulary assessment than children performing well in at least one of the memory measures. Comparing the current findings in terms of verbal STM with findings of Stokes and Klee (2009b), who revealed that nonword repetition was the strongest predictor of vocabulary scores before age; it could be argued that the age range in their study was less. They solely assessed verbal STM in two year old children, whereas the current study evaluated skills in two to five year old children. On that account, nonword repetition might have had more influence on vocabulary scores in their study. Another possible explanation might be that nonword repetition abilities are simply more important in very young children.

The current results are consistent with previous studies proposing that verbal STM is the driving force behind vocabulary development (de Abreu, et al., 2011; Gathercole & Baddeley, 1989). Nevertheless, it could be argued that the relationship between verbal STM and vocabulary might be interactive and, therefore, causal both ways. Some studies support this theory and suggest that a child’s language abilities significantly influence verbal STM performance (Gathercole, et al., 1997; Jarrold, et al., 2004). Moreover, Gathercole et al. (1992) suggest that verbal STM is a significant factor in predicting vocabulary skills but only before the age of five. On that account, the exact dynamics of working memory and language remain unclear; however, verbal STM still appears to be a good predictor early on in language acquisition. This is in agreement with the findings of the present study since all the children assessed were either five years or younger.

In addition, while the findings regarding the verbal component of the working memory reflects similarities with other studies, the visual STM contribution to vocabulary provides a new insight to language acquisition. The outcomes suggest that the visual STM has a greater impact on language development than previously assumed and similar findings were, to date, only reported by Nickisch and Kries (2009). Baddeley (2003b) argues that analogous to the role of verbal STM in language acquisition, visual STM appears to be relevant in the process of acquiring semantic knowledge of concrete objects and their utilisation. This is in line with the findings of the present study. Moreover, a study conducted by Duyck, Szmalec, Kemps, and Vandierendonck (2003), proposed that it is essential to distinguish between the acquisition of phonological representations (verbal STM) and acquiring word associations (visual STM) of new vocabulary. Word associations are defined as word imageability in the form of semantic and visual representations of objects or concepts (Duyck, et al., 2003). According to Duyck et al. (2003), word associations can be acquired by relying on other working memory components but verbal STM is solely restricted to phonological representations. Hence, verbal STM is involved in language development but as a consequence of unavailable visual clues (Duyck, et al., 2003). This theory provides an interesting line of thought on new word learning, in particular with respect to the results of the current study where visual STM appeared to be more important in vocabulary acquisition than verbal STM.

The differences in working memory contribution to receptive and expressive vocabulary might be explained by divergent processing demands of receptive and expressive language. Barton (as cited in Bernthal, Bankson, & Flipsen, 2009) found, with respect to sound acquisition, that speech perception was more advanced than speech production in typically developing two-year-old children. The same could be applied to vocabulary knowledge. Receptive language processing requires the recognition of language, whereas expressive language processing requires not only the recall of language, but also phonological representations and motor skills. Thus, speech production involves a higher processing load and, as a result, more processing skills than speech comprehension. On this account, visual and verbal short-term memory may become less relevant in receptive vocabulary development.

In summary, the association between vocabulary development and working memory abilities appears to be complex. The current study assessed the correlation between two components of working memory and children's vocabulary skills. It was established that visual and verbal STM and vocabulary knowledge are closely interrelated, particularly for expressive vocabulary. It was also found that visual and verbal STM are linked in combination with age, and the study further showed that memory performance increases as children get older.

4.2 Clinical Implications

The current findings may have direct implications for clinical practice with respect to assessment and intervention of some children presenting with SLI. Primarily, working memory tests could be considered to be included in assessment batteries for some children with SLI to ensure any cognitive deficits other than language are excluded. These tests, for example the VIP and TENR, could be used in clinical settings to elicit more complete data on cognitive abilities of individual children not only prior to treatment but also in the course of it. It seems that some children diagnosed with SLI are limited in their capability to develop language adequately even with frequent speech and language therapy intervention. Therefore, speech and language pathologists could attempt to maximise clients overall performance by adopting additional strategies that provide further assistance in acquiring new vocabulary. It seems plausible to assume that verbal STM deficits could be partially compensated by intact visual STM and vice versa. For example, children with deficits in visual STM might benefit from certain types of visual support to assist with retention and retrieval of new words. The same accounts for children with verbal STM deficits using strategies like rehearsal.

4.3 Limitations

A number of limitations were encountered while conducting the study that need to be addressed in order to minimise these negative effects for potential future research in the area of working memory and language.

Firstly, there was an overall lack of norm-referenced vocabulary measures on NZ English speaking children. On the account that there are currently no NZ English vocabulary tests available, American English vocabulary tests were used instead and some of the pictures were substituted with images of objects/actions/concepts more common in NZ. Hence, reported standard scores have to be viewed and interpreted with caution since they might not be representable for the children in NZ.

Secondly, informal discussion with most parents confirmed that the majority of children were from middle and upper-middle class families with parents holding a university degree. However, the questionnaire filled in by the parents only asked for the child’s birth order, siblings, ethnicity, medical condition and language/s spoken at home. It would have been valuable to add a further question asking about the socioeconomic status and educational background to augment participant data and interpret results accordingly.

The sample size was also a slightly limiting factor. Although it was moderate, a higher participant number and participants from different socioeconomic backgrounds may have reflected more language and working memory differences among the children, and a larger pool of participants would have provided greater validity to the findings of the study.

Moreover, some external factors that could not be controlled have had an impact on data collection. Several parents commented on the earthquakes and aftershocks in the Canterbury region and their stressful influence on performance and everyday life as a consequence. Thus, the performance of some children might have been affected in this study. Nevertheless, the whole extend of this factor is unknown. It should also be noted that these circumstances complicated participant recruitment in general.

4.4 Future Directions

The present study raises a number of questions requiring further research in the area of working memory and its influence on vocabulary development. First of all, it is of importance to ascertain more normative data with typically developing children for both visual and verbal STM. Roy and Chiat (2004) and Stokes and Klee (2009a) examined the diagnostic accuracy of nonword repetition with regard to verbal STM and language. Similar research in respect of visual STM tests might be valuable, especially with respect to intervention programmes in clinical practice.

Furthermore, it is important to determine whether similar results in terms of visual and verbal STM and expressive language would be found when studying a larger pool of participants. It would also be beneficial to study samples outside of New Zealand to determine if the same outcome applies not only for NZ English speaking children but also to children speaking British, Australian and American English or languages other than English.

Moreover, visual and verbal STM associations regarding receptive vocabulary require further investigations. Although a positive correlation with receptive vocabulary was observed in the current study, statistical significance could not be proved. However, a study with German speaking children, conducted by Nickisch and von Kries (Nickisch & von Kries, 2009), implied a significant association between receptive vocabulary and visual STM in children with diagnosed SLI. Hence, it might be interesting to duplicate the former mentioned investigation with English speaking children.

In regard to SLI, other cognitive measures beyond language could be investigated to provide a more holistic approach in speech and language pathology intervention. Logically, language studies with respect to working memory would provide a promising area of research examining children with SLI. An intervention study into the benefits of providing children with SLI not only with traditional language therapy but also with visual and verbal STM training might be worthwhile. This may involve the evaluation and comparison of children receiving speech and language intervention with and without additional working memory training, and could include measures prior to intervention and measures following intervention. Future findings might contribute to a better understanding of the fact that some children benefit more from intervention programmes and, therefore, show better treatment outcomes than others. As a result, this might help to develop more effective therapy concepts for some children presenting with SLI.

4.5 Conclusion

Overall, the results showed that receptive and expressive vocabulary was best predicted by age for the age range examined in this study. Children’s receptive vocabulary was predicted by age with 54% of the variance in receptive vocabulary accounted for. The amount of variance accounted for increased by 6%, when the two STM measures were added to age, but was not statistically significant. Thus, no meaningful relationship was found between receptive language and working memory over and above what was predicted by age. However, visual and verbal STM were both found to correlate significantly with expressive language knowledge. It was suggested that children's expressive vocabulary can be predicted by a combination of age and the two STM measures, with 69% of the variance in expressive vocabulary being accounted for. Despite the four year age range in this study, where age accounted for 60% of variance, the two STM measures accounted together for 9% additional variance. Moreover, it indicated that of the two STM measures, the VIP score seemed to be the more important. Hence, visual short-term memory seems to have a greater influence on expressive vocabulary than verbal short-term memory. Furthermore, the visual and verbal components of working memory appeared to be linked, but only in combination with age. The findings also suggest that both visual and verbal STM performance increase as children get older. In general, visual and verbal STM tests, such as the VIP and TENR, were found to be good predictors, over and above age, of children’s scores in language assessment, especially for expressive vocabulary. On this account, the results support the theory of working memory involvement in language acquisition. However, the explicit nature of these two working memory components and its specific contribution to vocabulary size, in particular the receptive one, is still not entirely known. More research in this area is required to gain a complete understanding of visual and verbal STM and its unique effects on language development.

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APPENDICES

APPENDIX A: TABLES

Table 1

Summary of Previous Research on Visual and Verbal Short-Term Memory and Language

Study	Ages	Sample Size and Place	Findings
Cognitive abilities in children with specific language impairment: consideration of visuo-spatial skills (Hick, et al., 2005a)	Mean CA: 3.9	18 children (UK) 9 children with SLI 9 TD children	Verbal STM Children with SLI performed poorer Visual STM Children with SLI showed slower development over time than TD children
Short-term memory and vocabulary development in children with Down syndrome and children with specific language impairment (Hick, et al., 2005b)	Mean age (mental): 4.3 CA DS: 9.9 CA SLI: 3.9 CA TD: 4.4	33 children (UK) 12 children with DS 9 children with SLI 12 TD children	Verbal STM Children with SLI and DS performed at a lower level than TD children Visual STM Children with SLI performed lower than DS and TD children and they showed a high variation in the scores
Visuospatial immediate memory in specific language impairment (Archibald & Gathercole, 2006)	Mean age (SLI): 9.8 Mean age (CAM): 9.8 Mean age (LAM): 6.0	45 children (UK) 15 children with SLI 15 CAM children 15 LAM children	Verbal STM Children with SLI were tested in a previous study and showed deficits in verbal STM Visual STM Children with SLI performed similarly to CAM children and at a higher level than the LAM children on various tasks
Short-term memory (STM) constraints in children with specific language impairment (SLI): are there differences between receptive and expressive SLI? (Nickisch & von Kries, 2009)	Ages: 6-11(mean CA not stated in article)	63 children (Germany) 21 children with ELI 21 children with R/ELI 12 Controls	Verbal STM Children with ELI and R/ELI performed at a lower level than the control group Visual STM Children with R/ELI performed at a lower level than the control group

Note. SLI = Specific Language Impairment; ELI = Expressive Language Impairment; R/ELI = Receptive/Expressive Language Impairment; TD = Typically Developing; STM = Short Term Memory; DS = Down Syndrome; CA = Chronological Age; CAM = Chronological Age Matched; LAM = Language Age Matched.

Table 2

Descriptive Statistics for each Measure

Measure	N	Mean	SE	SD	Range
ROWPVT (raw score)	51	51.10	2.70	19.27	3-93
ROWPVT (standard score)	51	112.53	2.47	17.62	54.5-145.5
EOWPVT (raw score)	49	47.59	2.63	18.46	6-85
EOWPVT (standard score)	49	112.58	2.05	14.35	74-145.5
VIP trials (percent)	51	53.92	3.38	24.17	8.33-100
VIP fish (percent)	51	78.62	2.06	14.69	47.62-100
TENR (PPC)	38	70.91	2.48	15.28	30.30-88.64
TENR 1syllable (PPC)	38	83.55	2.78	17.16	25-100
TENR 2 syllables (PPC)	38	76.16	2.34	14.41	35.29-94.12
TENR 3 syllables (PPC)	38	80.41	2.61	16.11	33.33-100
TENR 4 syllables (PPC)	38	72.30	2.75	16.98	16.67-91.67
TENR 5 syllables (PPC)	38	57.24	3.82	23.55	10-90

Note. Mean age of participants was 42.16 months (N = 51, SD = 12.04, Range = 24-63). ROWPVT = Receptive One Word Picture Vocabulary Test; EOWPVT = Expressive One Word Picture Vocabulary Test; VIP = Visual Patterns Test; TENR = Test of Early Nonword Repetition; PPC = Percent Phonemes Correct; SE = Standard Error of Mean; SD = Standard Deviation.

Table 3

Comparison of TENR Compliant Group and TENR Non-Compliant Group

Group	N	Mean	SE	SD	Range
TENR compliant					
Age (months)	38	45.34	1.82	11.23	27-63
ROWPVT (raw score)	38	55.08	2.88	17.74	21-93
EOWPVT (raw score)	38	51.71	2.77	17.10	19-85
VIP fish (raw score)	38	34.58	0.90	5.53	21-42
TENR (PPC)	38	70.91	2.48	15.28	30.30-88.64
TENR non-compliant					
Age (months)	13	32.85	2.62	9.44	24-51
ROWPVT (raw score)	13	39.46	5.41	19.51	3-68
EOWPVT (raw score)	11	33.36	4.91	16.30	6-54
VIP fish (raw score)	13	28.46	1.62	5.85	20-38
TENR (PPC)	-	-	-	-	-

Note. ROWPVT = Receptive One Word Picture Vocabulary Test; EOWPVT = Expressive One Word Picture Vocabulary Test; VIP = Visual Patterns Test; TENR = Test of Early Nonword Repetition; PPC = Percent Phonemes Correct; SE = Standard Error of Mean; SD = Standard Deviation.

Table 4

Bivariate Correlations for Vocabulary and Memory Measures

Variable	1	2	3	4	5	6	7	8	9	10
Age in months	.72***	.83***	.79***	.79***	.58***	.28	.24	.43***	.53***	.57***
1. ROWPVT	-									
2. EOWPVT	.82***	-								
3. VIP (trials)	.72***	.77***	-							
4. VIP (fish)	.75***	.80***	.92***	-						
5. TENR	.60***	.62***	.56***	.55*	-					
6. TENR (1)	.23	.14	.16	.21	.60***	-				
7. TENR (2)	.40*	.43***	.13	.12	.59***	.21				
8. TENR (3)	.47***	.54***	.47***	.43***	.84***	.48***	.61***	-		
9. TENR (4)	.42***	.50***	.55***	.56***	.86***	.60***	.35*	.63***	-	
10. TENR (5)	.63***	.61***	.55***	.53***	.91***	.39*	.45***	.66***	.68***	-

Note. Each correlation based on number of children for which data were available (N varies between 38 and 51). Raw scores were used for the ROWPVT and EOWPVT and percent correct was used for the VIP and TENR. ROWPVT = Receptive One Word Picture Vocabulary Test; EOWPVT = Expressive One Word Picture Vocabulary Test; VIP = Visual Patterns Test; TENR = Test of Early Nonword Repetition (one to five syllables).

* $p < .05$. *** $p < .001$, both one-tailed.

Table 5

Partial Correlations for Vocabulary and Memory Measures, Controlling for Age

Variable	1	2	3	4	5	6	7	8	9
1. ROWPVT	-								
2. EOWPVT	.61***	-							
3. VIP (trials)	.19	.36*	-						
4. VIP (fish)	.27	.40*	.78***	-					
5. TENR	.31*	.33*	.22	.21	-				
6. TENR (1)	.04	-.13	-.09	-.01	.56***	-			
7. TENR (2)	.35*	.41*	-.09	-.09	.57***	.15	-		
8. TENR (3)	.24	.36*	.24	.18	.80***	.42*	.58***	-	
9. TENR (4)	.06	.17	.27	.29*	.80***	.56***	.27	.53***	-
10. TENR (5)	.38*	.32*	.22	.19	.87***	.30*	.40*	.56***	.54***

Note. Each correlation based on number of children for which data were available (N varies between 38 and 51). Raw scores were used for the ROWPVT and EOWPVT and percent correct was used for the VIP and TENR. ROWPVT = Receptive One Word Picture Vocabulary Test; EOWPVT = Expressive One Word Picture Vocabulary Test; VIP = Visual Patterns Test; TENR = Test of Early Nonword Repetition (one to five syllables).

* $p < .05$. *** $p < .001$, both one-tailed.

Table 6

*Hierarchical Regression Analysis Summary for Age and Short-Term Memory Variables Predicting Children's Receptive Vocabulary Score (*N *= 38)*

Step and predictor variable	*B*	SE *B*	β	R^2	R^2 change
Step 1:				.54***	
Constant	2.44	8.34			
Age	1.16	0.18	.74***		
Step 2:				.60***	.06
Constant	-19.20	12.82			
Age	0.69	0.28	.44*		
Verbal STM	0.26	0.16	.22		
Visual STM	0.30	0.23	.22		

*$p < .05$. ***$p < .001$.

Table 7

*Three-Step Hierarchical Regression Analysis Summary for Age and Short-Term Memory Variables Predicting Children's Expressive Vocabulary Scores (*N *= 38)*

Step and predictor variable	*B*	SE *B*	β	R^2	R^2 change
Step 1:				.60***	
Constant	-1.99	7.45			
Age	1.18	0.16	.78***		
Step 2:				.65***	.044*
Constant	-12.11	8.62			
Age	0.96	0.19	.63***		
Verbal STM	0.29	0.14	.26*		
Step 3:				.69***	.044*
Constant	-28.01	10.89			
Age	0.62	0.23	.41*		
Verbal STM	0.23	0.13	.20		
Visual STM	0.43	0.20	.33*		

*p < .05. ***p < .001.

APPENDIX B: FIGURES

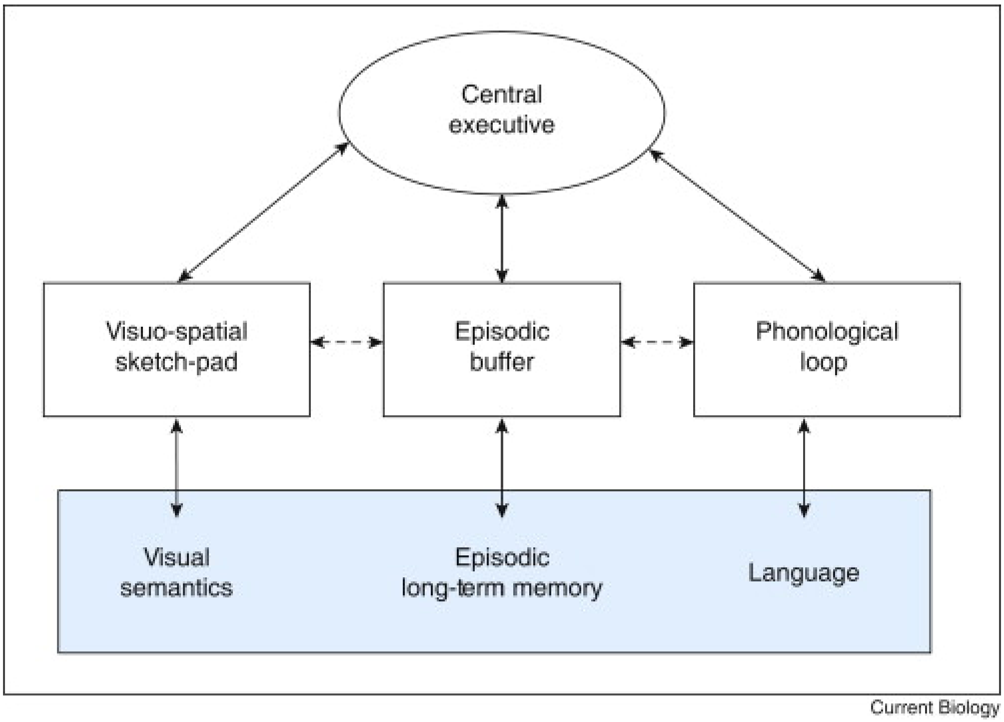

Figure 1. Baddeley's Model of Working Memory, from "Working Memory" by A. Baddeley, 2010, *Current Biology*, 20(4), R136-R140.

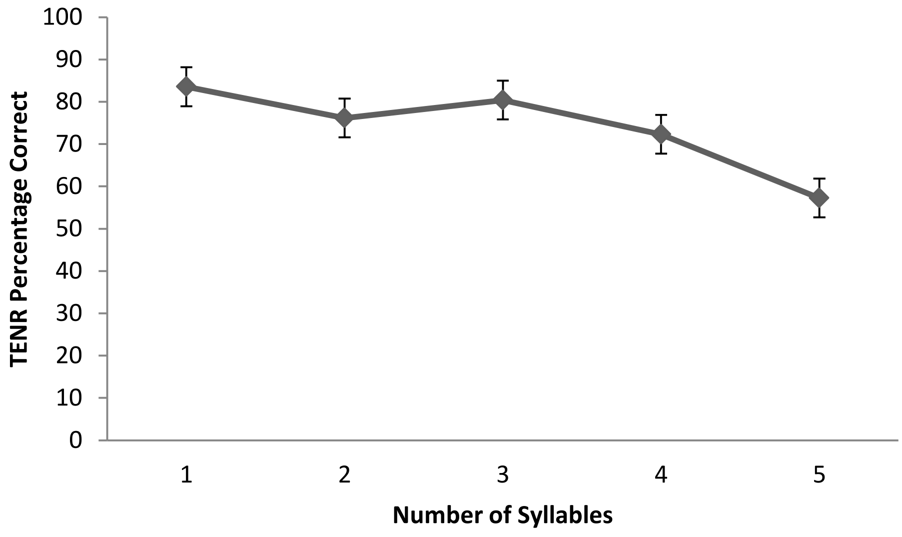

Figure 2. Mean Percentage of Phonemes Correct on Test of Early Nonword Repetition (N = 38). Error Bars Represent Standard Error of the Mean.

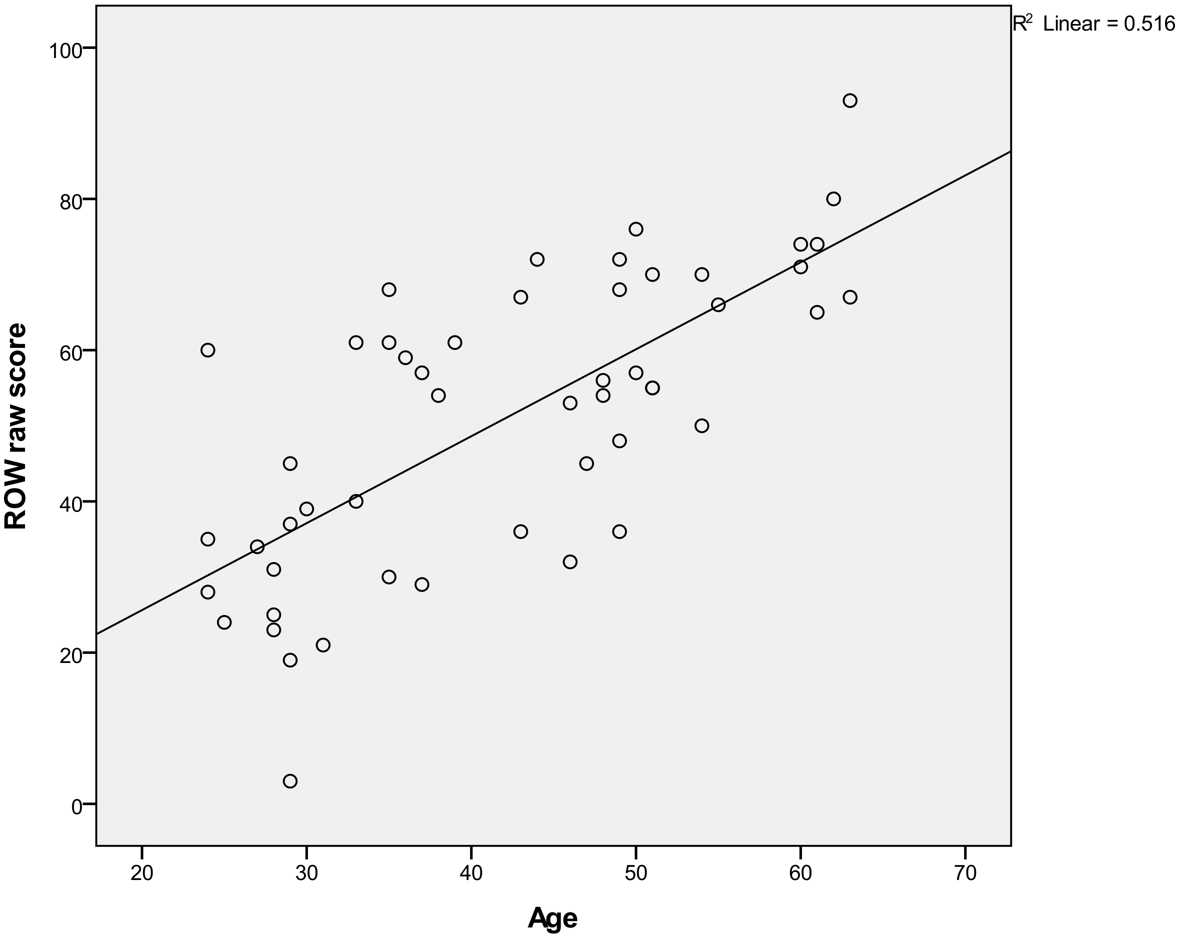

Figure 3. Scatterplot of Receptive One Word Picture Vocabulary Test and Age. ROW = Receptive One Word Picture Vocabulary Test.

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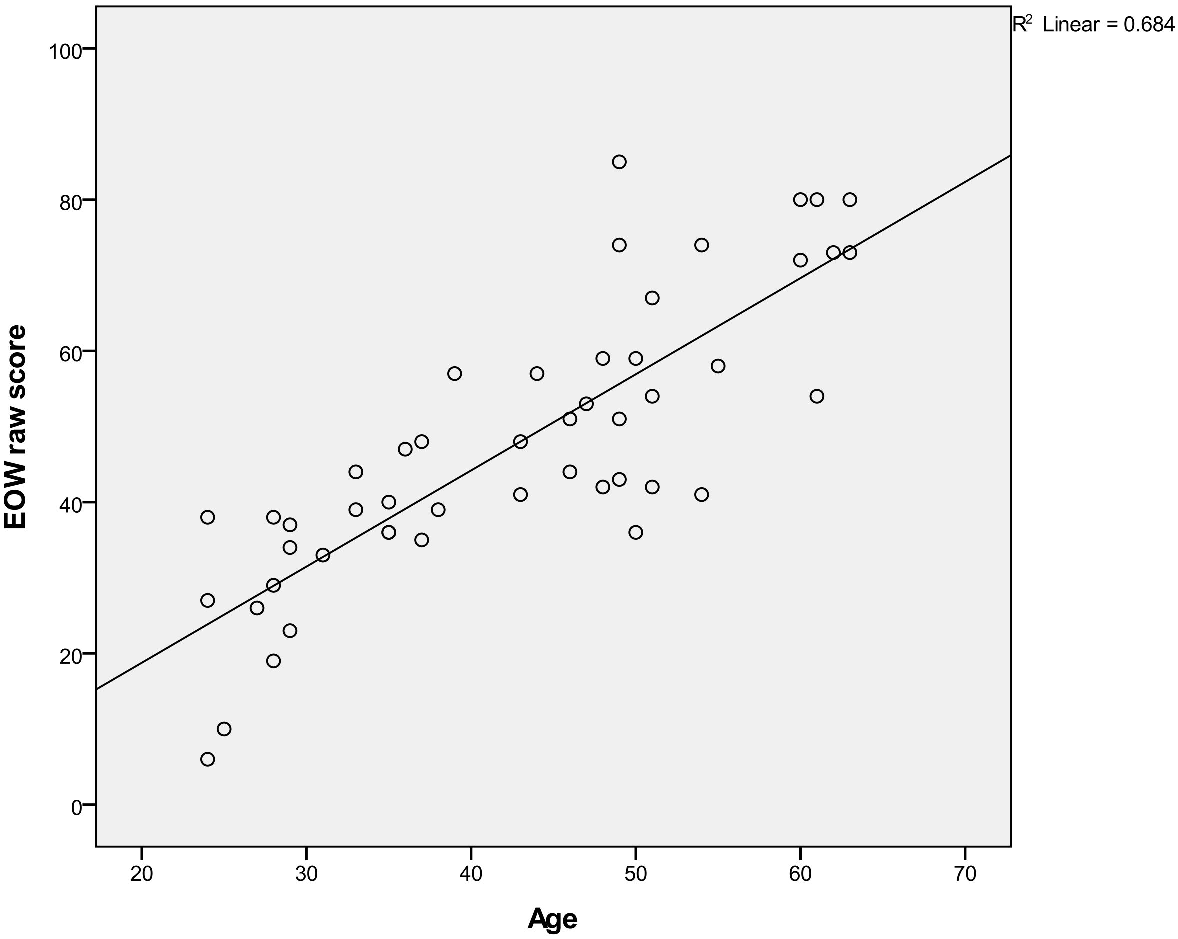

Figure 4. Scatterplot of Expressive One Word Picture Vocabulary Test and Age. EOW = Expressive One Word Picture Vocabulary Test.

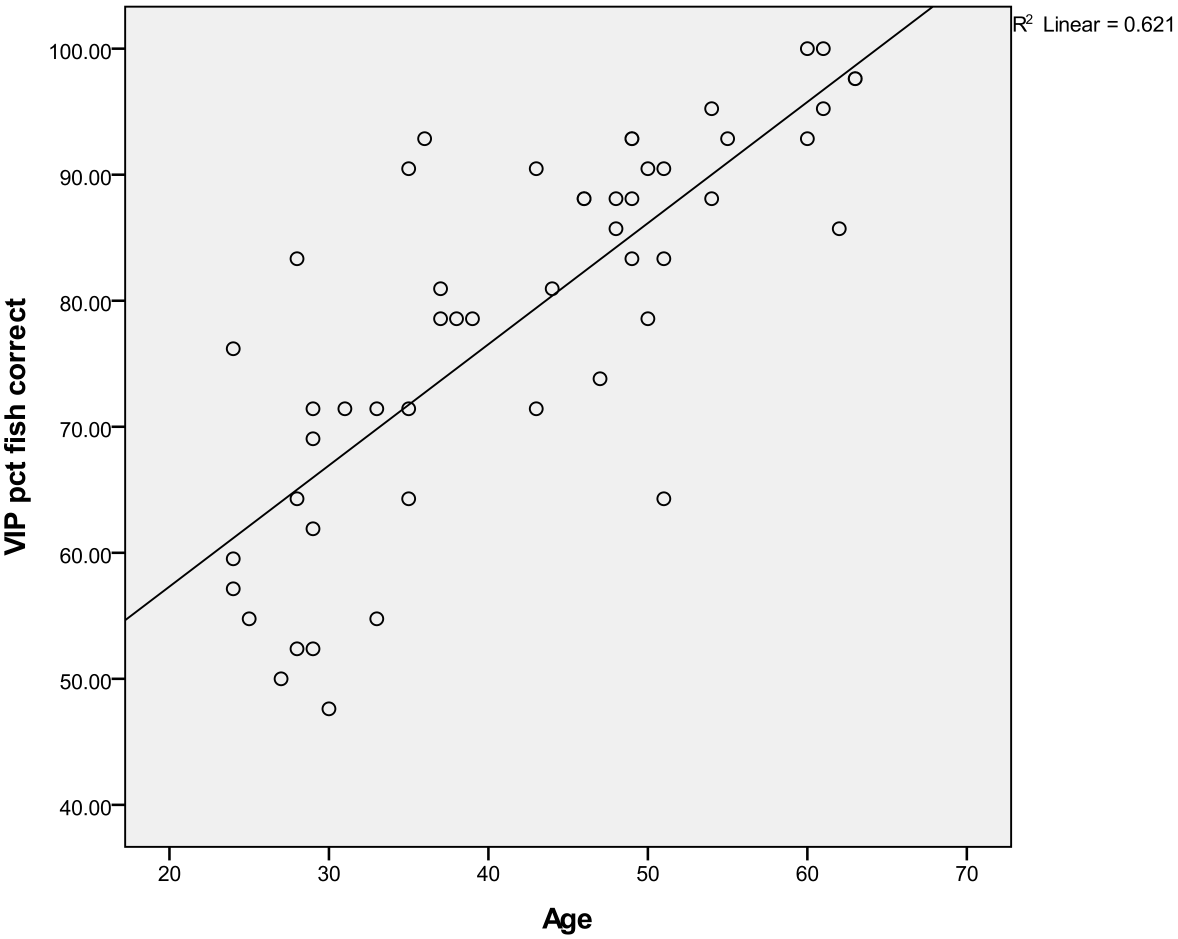

Figure 5. Scatterplot of Visual Patterns Test and Age.

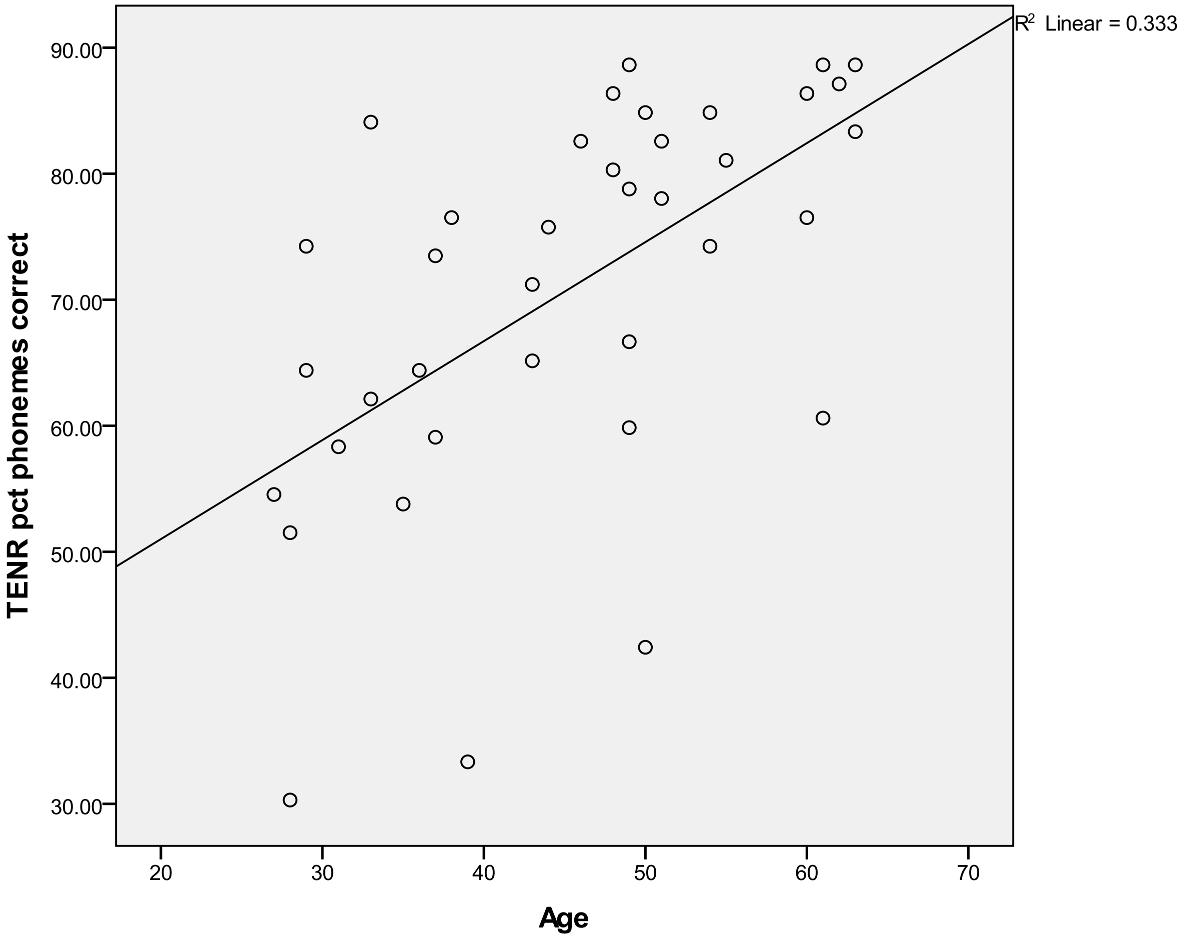

Figure 6. Scatterplot of Test of Early Nonword Repetition and Age.

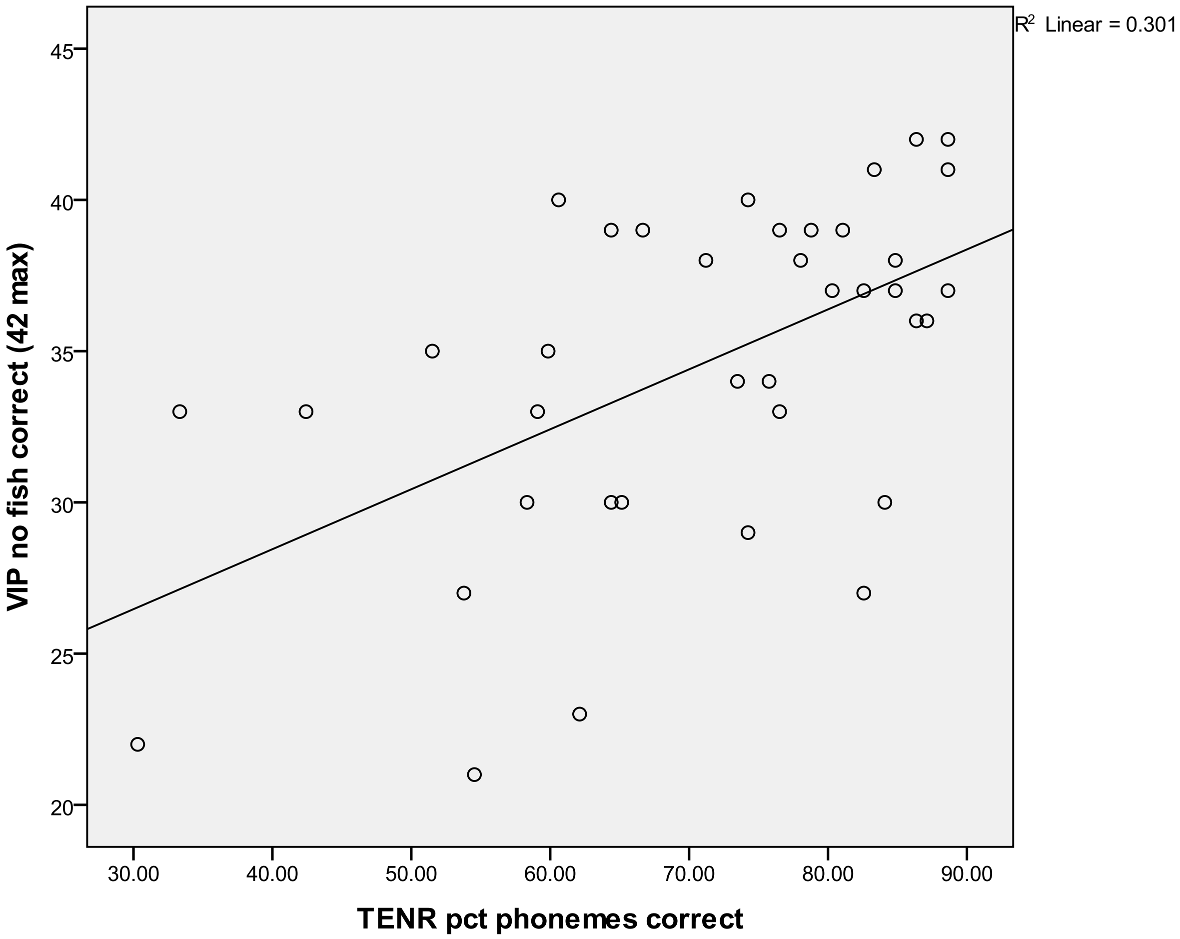

Figure 7. Scatterplot of Visual Patterns Test and Test of Early Nonword Repetition.

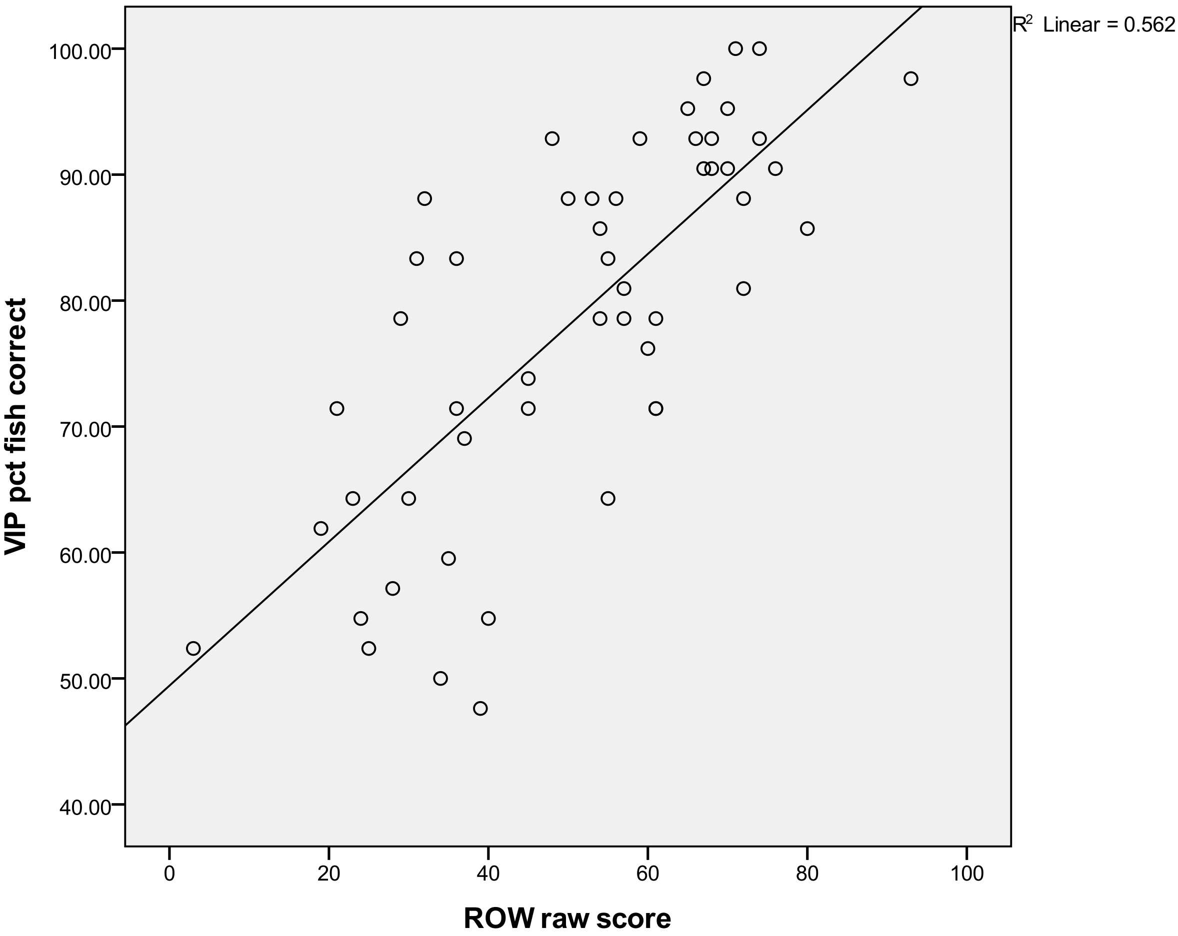

Figure 8. Scatterplot of Visual Patterns Test and Receptive One Word Picture Vocabulary Test. ROW = Receptive One Word Picture Vocabulary Test.

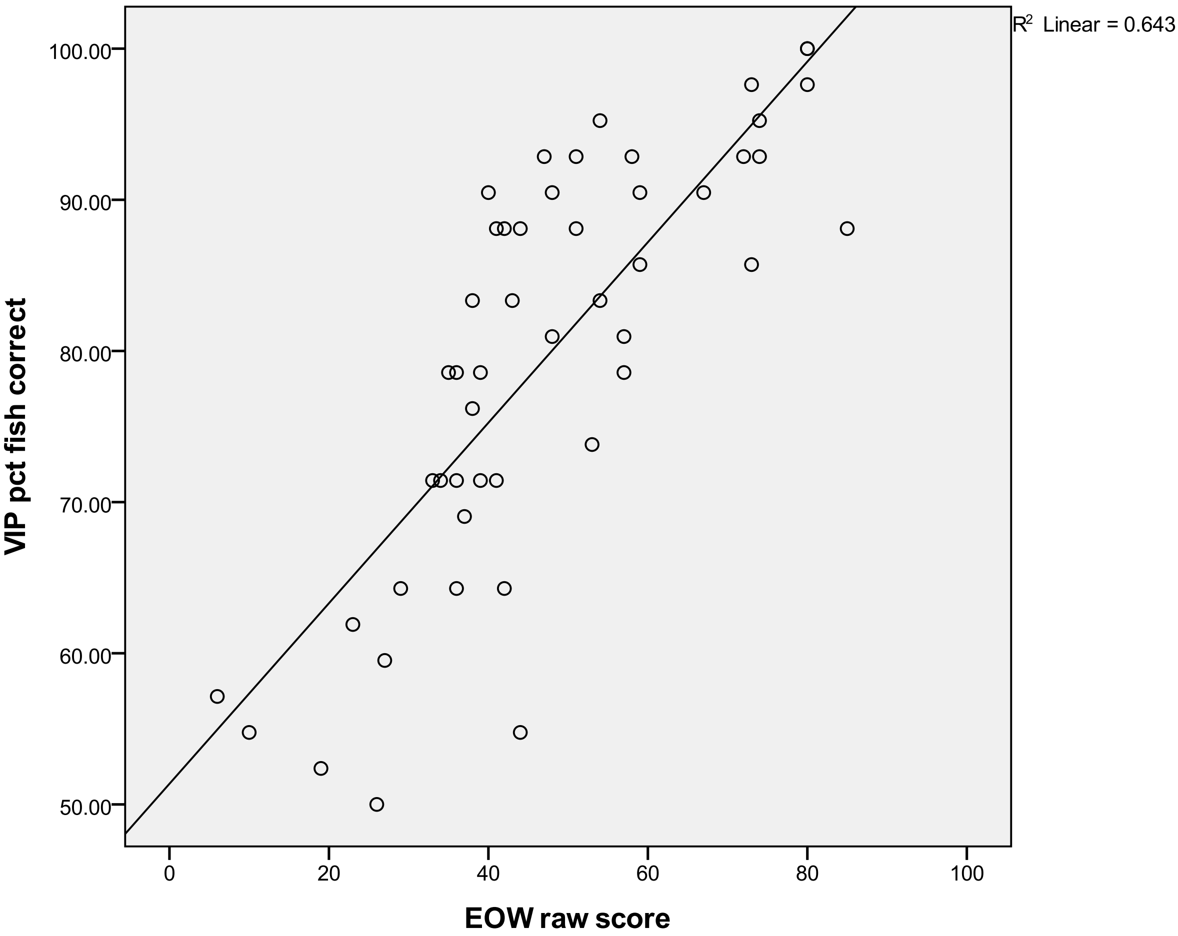

Figure 9. Scatterplot of Visual Patterns Test and Expressive One Word Picture Vocabulary Test. EOW = Expressive One Word Picture Vocabulary Test.

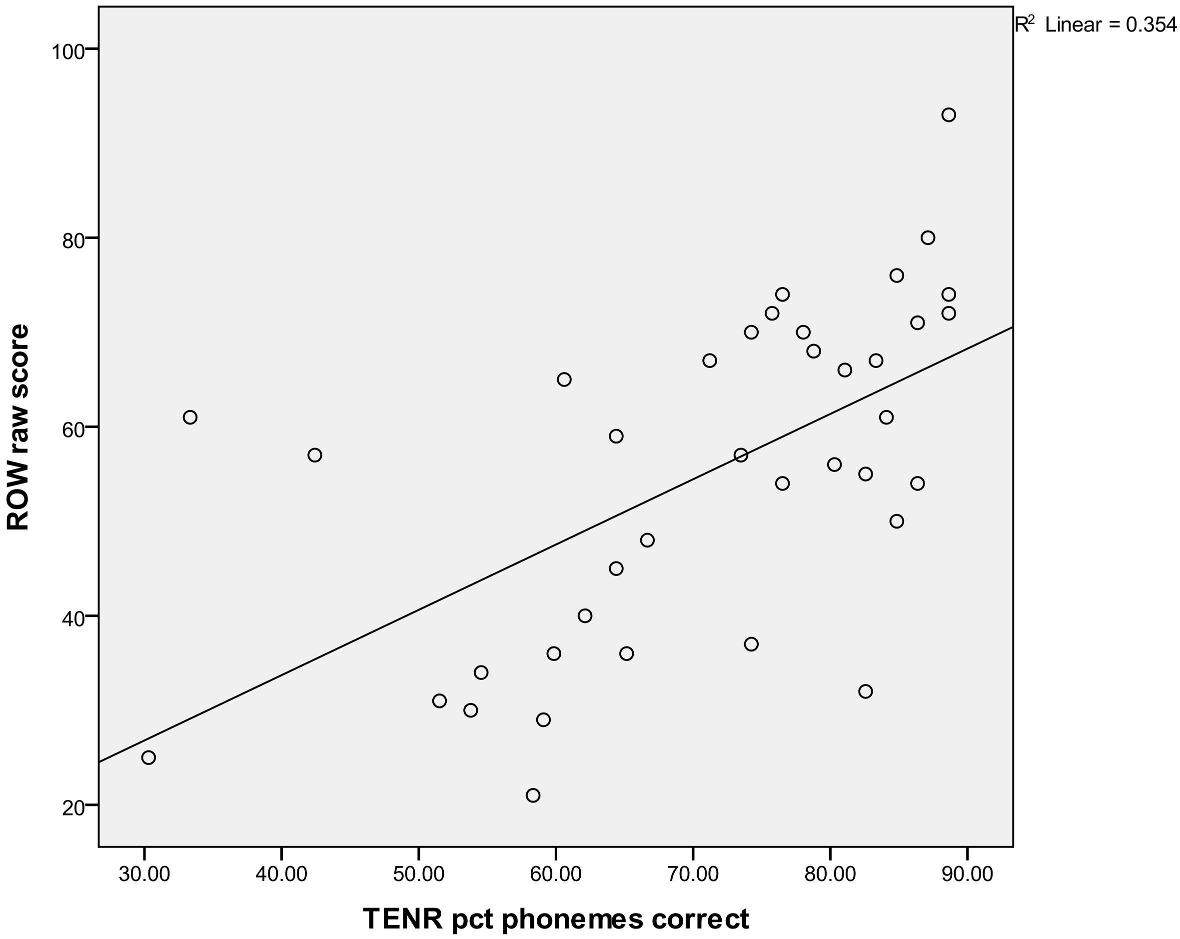

Figure 10. Scatterplot of Test of Early Nonword Repetition and Receptive One Word Picture Vocabulary Test. ROW = Receptive One Word Picture Vocabulary Test.

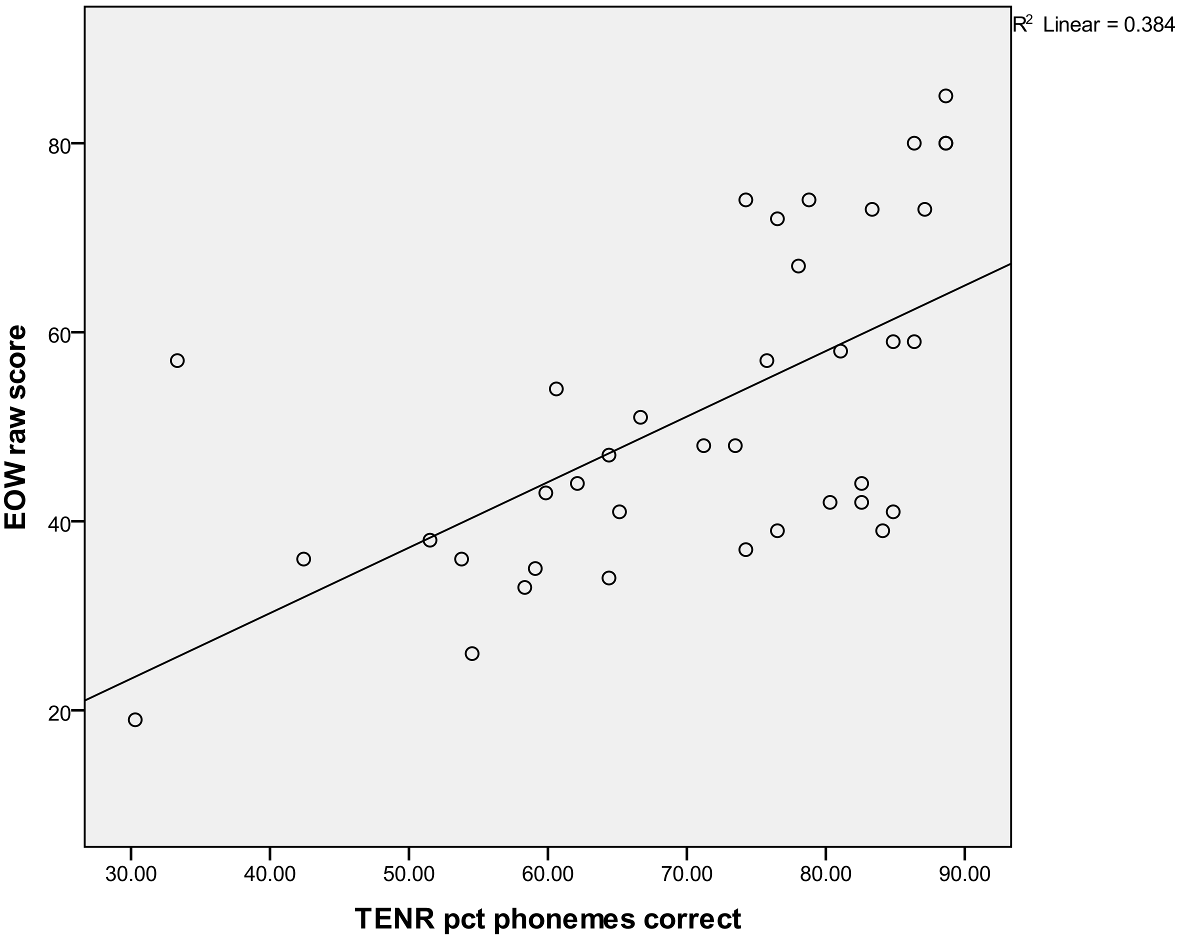

Figure 11. Scatterplot of Test of Early Nonword Repetition and Expressive One Word Picture Vocabulary Test. EOW = Expressive One Word Picture Vocabulary Test.

APPENDIX C: LEAFLET

Language and memory skills in preschool children

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

WE NEED YOU

Children aged 2-5 years

We study language development in children. We want to know why some children learn to talk very easily, while others struggle to do so. Some children don’t use words and sentences as well as other children of the same age. Why? One reason might be that children differ in their ability to learn because of differences in memory skills.

This is what we want to study, by testing your child’s

- Language skills (about 30 minutes)
- Memory skills (about 20 minutes)

If you agree, your child will be seen at his/her preschool for an hour (or at the Child Language Centre, 7 Creyke Rd, if you prefer), between May 19th and November 30th. You are welcome to be at the appointment with your child. Please contact us if you wish to help us by having your child participate.

For more information please email: myriam.kornisch@pg.canterbury.ac.nz or contact Myriam Kornisch on 021 027 39 322

APPENDIX D: INFORMATION SHEET

Language and memory skills in preschool children

Information sheet

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Dear (Parent/Caregiver),

I am writing to ask if you would like your child to be involved in our next language development study. This study is about language ability and memory skills. We want to know why some children learn to talk very easily, while others struggle to do so. Some children don't use words and sentences as well as other children of the same age. Why? One reason might be that children differ in their ability to learn because of differences in memory skills.

If you are happy for your child to join this study, your child will be seen at his/her preschool, and you are welcome to be there, if you are available. Your child will be seen by Myriam Kornisch. If you would rather, you can bring your child into our Child Language Centre (7 Creyke Road).

When we meet with you/your child, we will do two tests of vocabulary knowledge (about 40 minutes). Next, we will test the short-term memory skills of your child, using two games. In the first game your child repeats some made-up (nonsense) words that the adults says, and then rolls a toy car down a special board. We need to audio-record this game for later scoring. This takes 10 minutes. In the second game, your child sees fishbowls, some with fish, some without, on a computer touch-screen, and then the fish disappear. The game is for your child to touch the fishbowl where the fish was - a remembering game. This takes about 10 minutes. We will take play breaks between tasks so that we don't overload your child. Also, we can make a second appointment if your child indicates that he/she would like to stop. Or we can stop altogether if your child does not want to continue.

Your names and contact details will be noted initially, but then I will give every child a number, so that only I will know which child has which results from the tests/games. No names will be used in our reports. At the end of testing, we can tell you about your child’s vocabulary development and memory skills, if you want to know. If you would like, we can provide you with a summary of the research too. If you want to have more testing done after this project, I would be happy to discuss this with you (I am a speech-language pathologist).

If you want to join this project, please contact Myriam so that she can set up an appointment time for you. You will need to fill in the questionnaire, and sign the consent form on page 3 and either email/mail them to Myriam, or bring both sheets with you when you come to the Child Language Centre/preschool. You don’t have to take part in this study, you can say yes or no, and you can change your mind at any time if you don’t want to continue.
This project is being done by me, and Professor Thomas Klee, who works with me, and Myriam Kornisch. The project has been approved by the Human Ethics Committee of the University of Canterbury.

If you have any questions about the project please email Myriam on myriam.kornisch@pg.canterbury.ac.nz, or telephone 021 027 39 322.
or Professor Stephanie Stokes, on
stephanie.stokes@canterbury.ac.nz or 364 2987 (Ext 7084)

With thanks,

Professor Stephanie Stokes
Professor Thomas Klee
Ms. Myriam Kornisch (MSc student)
Physical Location:
Child Language Centre
7 Creyke Road, Ilam

Mail address:
Professor Stephanie Stokes
Department of Communication Disorders
University of Canterbury
Private Bag 4800
Christchurch, 8140

APPENDIX E: CONSENT FORM

Language and memory skills in preschool children

Consent form

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

12 May 2011

I have read and understood the information sheet for the language and memory study and hereby give my consent for my son/daughter __________________________________ (your child's name here), to join the project. This means that my child will be seen at his/her preschool or at the Child Language Centre. I understand that I can ask to withdraw from the study at any time. Stephanie Stokes or Myriam Kornisch has answered any questions that I have had. I note that one part of the testing will be audio-recorded for later scoring. I note that the project has been reviewed and approved by the University of Canterbury Human Ethics Committee.

Please print your name

____

Signed _______________________________________ Date ________________________

APPENDIX F: QUESTIONNAIRE

Language and memory skills in preschool children

Questionnaire

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Parent's name ____

Child's name ____

Child's date of birth ____________ Telephone number ____________________

Address ____

Postcode: ________ Email: ____

What is the best way to contact you? Phone ☐ Email ☐ Mail ☐

What is the sex of your child? Male ☐ Female ☐

Birth order of your child: 1^{st} born ☐ 2^{nd} born ☐ $3+^{rd}$ born ☐

How many children do you have? ☐

Was your child born prematurely? Yes by ☐ weeks No ☐

What ethnicities does your child identify with? ________________________

Does your child have any significant medical conditions? Yes ☐ No ☐

If yes, what medical conditions does your child have? ____________________

____

What language(s) is (are) spoken in your household? ____________________________

Is English your child's first language? Yes ☐ No ☐

Thank you

APPENDIX G: TEST OF EARLY NONWORD REPETITION

Child's Number__________________________ Date__________________

IPA target	IPA child response	Score		Target score	Target score no vowels
mad				3	2
neit				3	2
paim				3	2
bouk				3	2
kou gə				4	2
da fi				4	2
lɜ pou				4	2
fu pɪm				5	3
mou kɜ ri				6	3
dou pɜ lut				7	4
bæ lɜ kɒn				7	4
fi sai mɒt				7	4
pɜ du lə meip				9	5
fɛ nɜ rai sɛk				9	5
wu gɜ læ mɪk				9	5
lɒ dɜ næ tɪʃ				9	5
gi lɜ ma fu kou				10	5
lɜ tei di ku nei				10	5
gɔ lu mɜ fi nai				10	5
ba fu mou wu di				10	5
	TOTAL			132	72